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Status of the EPA (Environmental Protection Agency) Spray Painting Transfer Efficiency Research Program

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16. ABSTRACT The paper gives the status of a 5-year EPA research program on spray painting transfer efficiency. The objective of this program has been to develop a laboratory transfer efficiency measurement method, with the ultimate goal of a production-line-standardized transfer efficiency method. The EPA program was designed and initiated to develop the necessary background and research data to permit development of a standardized transfer efficiency test method. To ensure as broad participation in the program as possible, numerous sources in the industry were contacted and their assistance solicited where possible. In numerous instances equipment, personnel, and facilities were donated to support the program. Three systems are discussed: air-atomized conventional, air-atomized electrostatic, and airless spray.

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STATUS OF THE EPA SPRAY PAINTING TRANSFER EFFICIENCY RESEARCH PROGRAM

INTRODUCTION

Spray painting transfer efficiency is a measurement of how much paint solids actually coat a surface compared with the total paint available to coat that surface. Transfer efficiency measurements can be used to optimize on-line spraying or to develop more efficient spray equipment. More recently, however, the need to determine transfer efficiency has taken on a new aspect: transfer efficiency can be used to quantify volatile organic compound emissions from spray painting sources.

During the past 5 years the U.S. EPA and its contractor, Centec Corporation, Reston, Virginia, have been conducting extensive research on transfer efficiency. The objective of this research has been to develop a laboratory transfer efficiency measurement method with the ultimate goal of a production-line-standardized transfer efficiency method. Many companies have developed their own methods for determining transfer efficiency; however, these methods vary widely in efficiency and capability although most share common elements. This EPA research program was designed and initiated to develop the necessary background and research data to permit development of a standardized transfer efficiency test method. To ensure as broad participation in the program as possible, numerous sources in the industry were contacted and their assistance solicited where possible. In numerous instances, equipment, personnel, and facilities were donated to support the program. This paper addresses the status of the transfer efficiency measurement method development program for the air-atomized conventional and electrostatic systems.

OBJECTIVE

The program's objective is to develop a laboratory transfer efficiency

measurement method for potential application in a volatile organic compound emissions control stategy. It is not and has never been the objective of the program to determine the transfer efficiency of specific manufacturers' painting systems. Thus, the program's managers have been careful to conduct the program so that no conclusion on the capability of one manufacturer's system over another can be drawn.

APPROACH

Beginning in early 1982, three test series were conducted which defined the basic capability of the transfer efficiency measurement method. These tests indicated that the test procedure was viable with a standard deviation of no greater than 2.5 transfer efficiency units (i.e., a variance no greater than 6.25, standard deviation squared).

The program was divided into two phases. The objectives of Phase I were to develop the basic transfer efficiency measurement method and supporting research data. This would then permit verification testing in Phase II of the program without significant changes or modifications to the method developed in Phase I. Where changes were required to facilitate performance of the method, data would be available to verify the effect of the changes. The primary objectives of Phase I were to:

1) Identify existing and/or hybrid concepts for measuring transfer efficiency.
2) Select the best features of these concepts to develop the method.
3) Conduct laboratory tests to establish the precision of the formulated method.
4) Extend the test program to field-based laboratories (e.g., laboratories associated with manufacturers of spray coated products, equipment, and coatings) to establish the reproducibility of the method.

The precision goal set for the method was a standard deviation of 2.5.

The objective of Phase II was to verify the capability of the method to

perform to the defined precision limits across a number of laboratories. The precision goal for each of these tests was also set at a standard deviation from the mean of 2.5.

PHASE I. METHOD DEVELOPMENT

The first task of the program was to accumulate information on existing transfer efficiency test methods used by industry. A detailed literature search was conducted and information collected from equipment vendors, equipment users, and other industry and government experts in spray painting transfer efficiency measurement. In addition, a committee composed of industry and government experts was established to provide expertise to the program.

A preliminary test method was developed from the best qualities of 12 identified existing methods. Since it was desirable to have a controlled standardized procedure during the development phase of the method, a production line test was ruled out. Production line tests are usually made at production conveyor speeds using foil-coated dummy targets shaped like the workpiece to be painted. These characteristics are difficult to adjust across a a range of conditions, difficult to control, site-specific, and expensive to instrument at facilities unequipped for these measurements. Thus, the preliminary test method was developed as a laboratory method. In the 12 methods reviewed, the three measurements common to each for determining transfer efficiency were: the amount of solids in the paint, the amount of paint sprayed, and the amount of solids deposited on the substrate. In determining these values each presents its own unique problems which if not addressed could result in a source of error for transfer efficiency determinations. Thus, the procedure was developed to eliminate or minimize these errors.

Preliminary testing of the draft transfer efficiency method was conducted to establish whether the method could meet the following criteria:

1) Precision, defined by the standard deviation.
2) Ease of performance.
3) Cost of performance; i.e., facilities, labor, and equipment requirements.

In addition, strict quality control/quality assurance requirements were incorporated into the method to ensure data integrity.

Preliminary tests of the methodology were conducted at three laboratories, using air-atomized conventional, air-atomized electrostatic, and rotating atomized bell spray equipment. Three target configurations were examined. A flat stainless-steel panel target shown in Figure 1 was selected to simulate large flat workpieces. Foils, 14.24 cm (6 in.) wide, were mounted on the panel on 30.5 cm (12 in.) centers as the targets. A set of six 3.18 cm (1-1/4 in.) diameter aluminum cylinders also shown in Figure 1 were selected to simulate smaller, more open and intricate workpieces. A U-shaped semi-tube was used in one test series to simulate targets between the flat panel and vertical cylinders. Two test paints were used for preliminary testing: 65 weight percent solids polyester enamel paint and 52 weight percent solids acrylic enamel paint.

A number of spray conditions were specified to determine their effect on transfer efficiency. At each of the first three laboratories tested, the transfer efficiency results showed excellent repeatability, generally below a standard deviation of 2.5 for each equipment type. However, the overall transfer efficiency results for the same equipment type and coating at different laboratories were different.

The results of the Phase I evaluations allowed the research team to draw a number of important conclusions and to further refine the method. It was very apparent that the method produced repeatable intra-laboratory results with a high degree of precision as indicated in Table 1 which presents results for the first (Test I) and second (Test II) laboratory test series. The relative compactness of the results, as defined by the coefficient of variation, ranged between 0.1 and 5.5 percent for air-atomized conventional and air-atomized electrostatic systems, respectively. Since the within laboratory repeatability was shown to be consistent, the logical conclusion was that the variation in transfer efficiency results across laboratories was due to differences between laboratories. The test conditions could not be controlled to the same degree for each laboratory.

Table 1 summarizes the Phase I, Test I and II, results for the air-atomized electrostatic system and the air-atomized conventional system.

PHASE II -- INTERLABORATORY TEST PROGRAM

Confidence in the satisfactory performance of the test method was established during the series of preliminary laboratory experiments conducted during Phase I. The method performed consistently under a standard deviation of 2.5 (the projected maximum acceptable standard deviation) for replicate determinations made at each laboratory. These tests were conducted on a wide range of equipment types, including conventional airspray and air-atomized electrostatic spray equipment.

Given this confidence, Phase II of the program was structured to establish the interlaboratory characteristics of the method. Phase I successfully quantified the within-laboratory component of the variance (σ_w^2); Phase II was designed to quantify the between-laboratory portion of the variance (σ_b^2). To achieve this goal, it was necessary to estimate the number of laboratories needed to participate. Data from Phase I could not be used for these evaluations because modifications had been made to the method between the tests, thus invalidating that data for use in Phase II. In addition, certain test parameters had not been held constant between each of the Phase I tests. In the absence of usable data, the number of laboratories required was estimated based on guidelines from the American Society for Testing and Materials (who recommend a minimum of 10 laboratories)(1) and the Association of Official Analytical Chemists (who recommend a minimum of 5 or 6 laboratories).(2) A decision was made to use eight laboratories in the program. To corroborate the selection of eight laboratories for Phase II, a sequential experimental design was selected.

In sequential experimental design, two tests are conducted and the results used to estimate the number of laboratories required to meet precision criteria. As subsequent tests are performed, the numbers of laboratories required are also successively estimated. This experimental design allows

estimation of interlaboratory characteristics which truly reflect the level of knowledge at a given point in the program.

A list of criteria was developed for qualifying laboratories to participate in the program. These criteria were selected based on information developed earlier in the program, and on the resources needed at each participating laboratory. The criteria are given in Table 2.

There was concern that the interlaboratory characteristics of the method might vary with spray equipment type (spray mechanism) or with the value of transfer efficiency. To detect these phenomena, three types of spray systems were selected for this program: air-atomized electrostatic, air-atomized conventional, and airless spray systems. The equipment types and their operating conditions were selected to yield a wide range of transfer efficiency values. Airless spray equipment was desirable not only to provide range, but to ensure that the methodology was applicable to previously untested airless equipment.

The industry and government committee reviewed the experimental design, and added another variable of concern: since eight separate spray guns were to be used at eight laboratories, the committee was concerned that spray characteristics (therefore transfer efficiency) could vary from gun to gun. This situation could confound interpretation of the test results. Based on their experience, spray characteristics (thus transfer efficiency) could vary even when using the same make, model, and operating conditions. While part of this difference might be attributed to differences in the condition of the guns (a worn tip versus a new tip, for example), there was concern that production abnormalities in the guns could introduce an uncontrolled variable.

To avoid this pitfall, the experimental design was revised to include testing for the portion of the variance due to differences between guns (σ_g^2). This part of the test included using eight spray guns (six replications apiece) at the first laboratory under the same operation conditions. This experiment allowed estimation of the portion of the variance due to differences between spray guns. Each of the spray guns used at the first laboratory was new, was selected at random, and was used only once subsequent to the first test at one

of the participating laboratories. Thus the spray guns were all in the same condition for the test program.

The final experimental design provided for six replicate transfer efficiency determinations to be made for each equipment type at eight participating laboratories. Additional tests were made at the first laboratory to estimate the gun portion of the variance.

The test program began in June 1985, and lasted through December 1985. The first test confirmed that a range of transfer efficiencies had been achieved. Data were obtained from the low 30s to the high 70s (in units of transfer efficiency) for different equipment types.

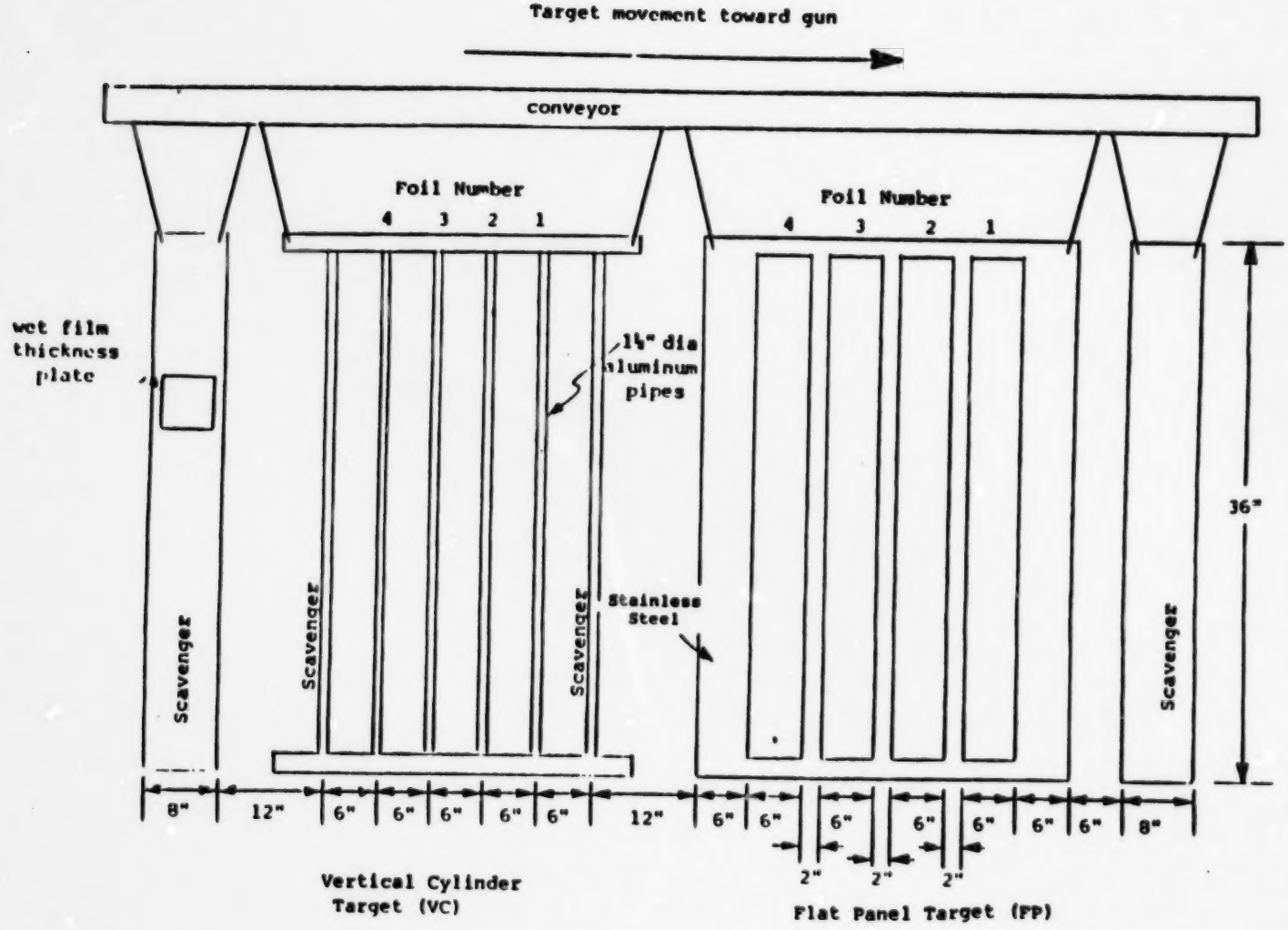
Statistical analyses using the results of subsequent laboratory tests confirmed that eight laboratories would be needed to complete the program. A preliminary statistical analysis of the data was completed in February 1986.

A statistical analysis was made to determine the components of variance, σ_w^2, σ_b^2, and σ_g^2. These components are additive to form the total variance, σ_t^2. The analysis was performed to determine what portion of the total variance was due to the differences between guns, what portion could be attributed to within-laboratory variance, and what portion was truly due to differences between laboratories.

At this time a preliminary statistical analysis of the interlaboratory data has been completed. The gun portion of the variance was small. It ranged from less than 1 for one gun to 13 standard deviations squared for another. The gun portion of the variance, however, could not be shown to be related to the total variance or to the mean transfer efficiency.

Similarly, the within-laboratory portion of the total variance was small. The within-laboratory variance target was 6.25 (2.5 standard deviations squared). The within-laboratory portion of the variance in Phase II did not exceed 3.3, thus falling well within the target value.

The between-laboratory portion of the total variance was overwhelmingly the largest, implying that the differences were real, detectable by the method, and quantifiable. The between-laboratory variance ranged from about 22.7 to 46.9 (standard deviations squared) for the three equipment types tested. The total standard deviation between laboratories was approximately 5.5 for air-atomized conventional equipment, 7.0 for air-atomized electrostatic equipment, and 7.1 for airless equipment. At 80 percent confidence, the mean transfer efficiency at one laboratory would be expected to be less than 9.2 transfer efficiency units different from the results at another random qualifying laboratory. These are preliminary "worst case" results, based on an incomplete engineering analysis. This information should not be used until that analysis is completed. However, it is indicative of the precision expected from the method when used in a laboratory.



NOTE:
1" = 2.54 cm

Figure 1. Target Configuration For Preliminary Transfer Efficiency Tests.

Table 1. Summary of Transfer Efficiency Results for Phase I Testing

Test Series		Test I			Test II		
		TE_M%	S%	COV%	TE_M%	S%	COV%
AAE-VC	Low Solids	30.8	1.7	5.5	61.8	2.1	3.4
AAE-FP	Low Solids	81.2	0.2	0.4	90.7	2.4	2.6
AAE-VC	High Solids	25.7	0.4	1.6	51.5	1.8	3.5
AAE-FP	High Solids	81.5	1.7	2.1	90.3	1.7	1.9
AAC-VC	Low Solids	10.8	0.1	0.9	15.8	0.2	1.8
AAC-FP	Low Solids	61.7	0.5	0.8	76.5	0.8	1.0
AAC-VC	High Solids	10.2	0.04	0.4	14.7	0.5	3.4
AAC-FP	High Solids	60.8	0.04	0.1	75.5	2.1	2.8

TE_M Mean transfer efficiency: $\frac{\Sigma TE_n}{M}$

n Number of test runs

S Standard deviation: $\frac{\left[\Sigma(TE_n - TE_M)^2\right]^{1/2}}{n-1}$

COV Coefficient of variation: $\frac{S}{TE_M} \times 100\%$

AAE Air-atomized electrostatic

AAC Air-atomized conventional

VC Vertical column

FP Flat panel

Table 2. Transfer Efficiency Method Evaluation Program
Latoratory Selection Criteria

1. A minimum of one technician, knowledgeable and proficient with spray system use and maintenance

2. Back-draw water wash spray booth with 100 fpm (50.80 cm/sec) air velocity in the middle at the plane of the targets, and no more than +20 fpm (10.16 cm/sec) across the profile

3. Adjustable-rate overhead conveyor system capable of hanging EPA targets

4. Conveyor speed measurement equipment

5. Paint mixing and documentation equipment

6. Oven of sufficient size for curing targets, with temperature control

7. Timer

8. Air rate measurement equipment

9. Humidity and temperature measurement equipment

10. Foil cutting and handling facilities

11. Laboratory scales

12. Hangers for targets

13. Temperature control in laboratory to 75°F (23.9°C).

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